VIBRATING DEVICE AND TACTILE SENSE PRESENTING DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of International application No. PCT/JP2015/065983, filed on Jun. 3, 2015, which claims priority to Japanese Patent Application No. 2014-118332, filed on Jun. 9, 2014, the entire contents of each of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a vibrating device including a diaphragm which is caused to vibrate when a driving voltage is applied to a piezoelectric film attached thereto, and a tactile feedback device which transmits the vibration of the vibrating device as tactile feedback to a user.

BACKGROUND ART

[0003] A vibrating device which includes a diaphragm vibrated by driving a piezoelectric film is used in a flat speaker or a haptics device (a tactile sense presenting device) as described, for example, in WO2012-0157691.

[0004] FIG. **9**(A) is a side view of a vibrating device **101** employing a conventional configuration, and FIG. **9**(B) is a top view of the vibrating device **101**. The vibrating device **101** includes a piezoelectric film **102**, a diaphragm **103** and frame members **104** and **105**. The diaphragm **103** and the piezoelectric film **102** have rectangular shapes which are elongated in a length direction (the vertical direction as viewed in FIG. **9**(B)). The piezoelectric film **102** is formed by stretching a PLLA (poly-L-lactic acid) film in a stretching direction (indicated by outlined arrows in FIG. **9**(B)) and cutting the stretched PLLA film out in such a manner that the length direction of the piezoelectric film **102** forms a 45° angle with respect to the stretching direction. The piezoelectric film **102** formed in this way stretches and contracts in the width direction when a voltage is applied thereto. The frame members **104** and **105** are provided at opposite ends of the piezoelectric film **102** and extend in the length direction. Opposite ends of the diaphragm **103** are connected to the piezoelectric film **102** by the frame members **104** and **105**, respectively. The diaphragm **103** flexes such that a center of the diaphragm **103** in the width direction is spaced apart from the piezoelectric film **102** (see FIG. **9**(A)) and that the frame members **104** and **105** apply a tensile force to the piezoelectric film **102** in the direction of the solid arrows in FIG. **9**(*a*). When an AC voltage is applied to the piezoelectric film **102**, it vibrates in the width direction and the curvature of the diaphragm **103** fluctuates along with this vibration.

[0005] In the haptics device of FIGS. **9**(A) and **9**(B), a downward pressing force applied to the diaphragm **103** in the thickness direction may cause the diaphragm to flatten and become parallel to the piezoelectric film. When this happens, the diaphragm barely vibrates even when the piezoelectric film is vibrated in the width direction (the horizontal direction in FIG. **9**(A)). As a result, it is difficult to provide the user with a tactile feedback. To prevent the diaphragm from being pushed and flattened, the diaphragm may be made thick and rigidity of the diaphragm may be improved. However, when this is done, the amount of the diaphragm bends becomes small and it is difficult to provide a tactile feedback to the user.

[0006] It is therefore an object of the present invention to provide a vibrating device and a tactile sense presenting device which can bend a diaphragm in a thickness direction from a flat state and can easily increase the amount the diaphragm bends in response to the vibration of the piezoelectric film.

SUMMARY OF THE INVENTION

[0007] A vibrating device according to the present invention includes a flexible diaphragm and a film which deforms in response to the application of electrical energy thereto. The film is attached to the flexible diaphragm at two spaced locations with a major surface of the film facing a major surface of the flexible diaphragm. A spacer is located between the two spaced locations and ensures that the major surface of the flexible diaphragm is spaced from the major surface of the film.

[0008] The vibratory device preferably has a length, a width and a height. The flexible diaphragm and the film are spaced apart in the height direction and the flexible diaphragm is flexible in the height direction. The flexible diaphragm deforms in response to deformation of the film when electrical energy is applied to the vibratory film. More preferably the diaphragm vibrates in response to vibration of the film when an alternating electric voltage is applied to the vibratory film.

[0009] The spacer preferably contacts both the diaphragm and the film both before electrical energy is applied to the film and after it is applied to the film. The spacer preferably includes a base portion facing the film and a plurality of protrusion portions facing the diaphragm. The base portion is preferably in contact with the film and the plurality of protrusions are preferably in contact with the diaphragm.

[0010] The vibrating device preferably has a length, a width and a thickness extending perpendicular to one another and the spacer is elongated and extends in length direction of the vibrating device. Preferably the plurality of protrusions extend in the thickness direction of the vibrating device and a plurality of the spacers are aligned in the length direction of the vibrating device.

[0011] In one embodiment, the diaphragm has a flat shape when electrical energy is not applied to the film. In others, it is curved. The film preferably comprises a chiral polymer film or a polyvinylidene fluoride film.

[0012] As a result of the foregoing structures it is possible to reliably bend/vibrate the diaphragm in the thickness direction by driving the film even when the diaphragm is in a flat state. Further, even when the diaphragm is thin and not very rigid, a gap between the diaphragm and the film is maintained. Consequently, it is possible to make the diaphragm thin and less rigid and increase the amount of flexure in the diaphragm.

[0013] The spacer is preferably provided between the diaphragm and the film and is in contact with the diaphragm and the film at all times. According to this configuration, the spacer can be sandwiched between and held by the diaphragm and the film.

[0014] In some embodiments, a plurality of the spacers are preferably aligned in the length direction of the vibrating device. The positions of the spacers are such that they define nodes of a vibration of the diaphragm when electrical energy is applied thereto. The harmonic can be set to an appropriate